

EV 263586066 US

1

RN02097

COMPOSITION BASED ON HYDRAULIC BINDER

The present invention relates especially to a composition for manufacturing an article comprising one or more superposed layers each less than 5 centimetres thick, comprising a hydraulic binder and at least one compound chosen from an organic compound comprising at least two hydrophilic functions and a hydrophobic chain, and a polyamide oligomer.

10 The use of these additives in the presence of hydraulic binder allows the manufacture of articles and coatings with good protection against water uptake and cracking, satisfactory water resistance and good mechanical properties such as breaking strength.

15 Hydraulic binders are generally cements based on calcium silicates and/or mineral aluminates or plasters based on calcium sulphate used in numerous industries, particularly in the construction field for making the infrastructure of buildings, works of art,
20 apartment buildings or articles such as paving slabs or boards and tiles.

Hydraulic binders may also be reinforced with fibres for the manufacture of fibrocements used, for example, as a material for making articles for covering
25 roofs, pipework or tanks.

Hydraulic binders are manufactured from

temperature and converted into mineral compounds capable of reacting with water to produce a binder, which, after curing, forms a compact mass with good mechanical properties.

5 However, the articles obtained with the hydraulic binders known in the prior art react with water over time. The penetration of water causes efflorescences to the surface of the articles, resulting from carbonatation phenomena, and may
10 possibly lead to a degradation in the mechanical properties. The penetration of water is generally accompanied by a low resistance of the structures to the freezing/thawing cycle.

 Similarly, during their drying, thin articles
15 encounter problems of cracking, caused especially by evaporation of water.

 Such phenomena can affect the mechanical properties and the durability of the articles or works made with such a binder.

20 As hydraulic binders presenting such drawbacks, mention may be made of: Portland cement, aluminous or high alumina cement, quick-setting cement and natural cements of Vicalpe and Rapide type.

 There is thus a need for a hydraulic binder
25 that has good mechanical performance and low water absorption to overcome the drawbacks mentioned previously.

It has been found that the use of additives such as an organic compound comprising at least two hydrophilic functions and a hydrophobic chain and/or a polyamide oligomer comprising a low number of repeating
5 units in the presence of hydraulic binder allows the manufacture of articles and coatings with good protection against water uptake and satisfactory water resistance.

The articles or coatings according to the
10 invention obtained using a composition comprising a hydraulic binder and these additives also have good mechanical properties such as breaking strength and resistance to cracking.

Very good results have especially been
15 observed on articles comprising one or more superposed layers each less than 5 centimetres thick.

The present invention relates to a process for manufacturing an article comprising one or more superposed layers each less than 5 centimetres thick,
20 obtained by using a composition comprising a hydraulic binder and at least one compound chosen from:

- an organic compound comprising at least two hydrophilic functions and a hydrophobic chain, and
- a polyamide oligomer comprising less than 20
25 repeating units, preferably less than 10 repeating units.

Processes for manufacturing an article of

cement or fibrocement type are widely known in the prior art. Mention may be made, for example, of the Hatscheck process for the manufacture of fibrocements, or any process known to those skilled in the art for
5 the manufacture of cement materials (for example pouring, injection or spraying).

Generally, the hydraulic binder is mixed with a composition comprising water and additives to form the articles. The composition may optionally be heated
10 and/or blended before leaving it to set to a solid, for example in a mould.

Depending on the articles that it is desired to obtain, a person skilled in the art is entirely capable of manufacturing them from a composition
15 according to the invention comprising a hydraulic binder.

According to the invention, additives such as the said organic compound, the polyamide oligomer or fibres, latex and a water-soluble amphiphilic copolymer
20 may be added to the composition extemporaneously at the time of manufacture of the article. It is also possible for these compounds to be added to the dry hydraulic binder.

Preferably, the composition according to the
25 invention comprises a latex and/or fibres.

According to the invention, the composition preferably comprises from 0.05% to 10% by weight of the

said organic compound relative to the total weight of hydraulic binder.

Preferably, the composition comprises from 0.05% to 10% by weight of polyamide oligomer relative to the total weight of hydraulic binder.

In the case where latex is added to the composition according to the invention, it can represent from 0.1% to 15% by weight relative to the total weight of hydraulic binder.

10 Preferably, the composition may comprise from 0.1% to 10% by weight of fibres relative to the total weight of hydraulic binder.

The said organic compound comprising at least two hydrophilic functions and a hydrophobic chain
15 advantageously comprises acid, acid halide and/or acid anhydride functions. The hydrophobic chain may be chosen from aliphatic, arylaliphatic, aromatic and alkylaromatic chains. This hydrophobic chain may comprise from 2 to 30 carbon atoms and preferably from
20 4 to 13 carbon atoms.

Preferably, the organic compound is chosen from the group consisting of succinic acid, sebacic acid, adipic acid, octanedioic acid, decanedioic acid, dodecanoic acid, brassylic acid and glutaric acid, and
25 also the salts, derivatives and/or mixtures thereof. For example, the organic compound may be a mixture of adipic acids, glutaric acid and succinic acid or a

mixture of acids for the manufacture of adipic acid. The salts of these organic compounds are preferably soluble in an aqueous medium and may be, for example, sodium, potassium, ammonium and/or diamine salts.

5 According to the invention, the polyamide oligomers are preferably obtained from polyacid monomers, such as adipic acid, polyamine monomers, such as hexamethylenediamine, and/or amino acid monomers, such as ϵ -caprolactam. The polyamide oligomers are
10 preferably obtained from adipic acid and hexamethylenediamine. These two monomers may be used in the oligomer in stoichiometric or non-stoichiometric proportions, for example with an excess of one of the two monomers that may be up to 50%. The polyamide
15 oligomers may bear a function chosen, for example, from phosphates, phosphonates, sulphonates, alkoxysilanes, dicarboxylates, aminocarboxylates, anhydrides, epoxys and diols. An oligomer obtained from adipic acid, hexamethylenediamine and another monomer comprising the
20 functions mentioned above, such as two carboxylic acid functions and one sulphonic acid function, for example the sulphonated isophthalic acid AISNa, may preferably be used.

 Preferably, the latex is a water-insoluble
25 film-forming polymer prepared from at least one ethylenically unsaturated monomer. The said ethylenically unsaturated monomer may be chosen from

styrene, butadiene, C₁-C₁₂ alkyl acrylic or methacrylic esters and the corresponding acids thereof, and vinyl esters. Advantageously, the water-insoluble film-forming polymer is chosen from the group consisting of vinyl or acrylate homopolymers, and copolymers of vinyl acetate, of styrene/butadiene, of styrene/acrylate, of acrylic esters and of styrene/butadiene/acrylate.

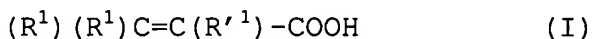
According to one particular embodiment of the process of the invention, the composition of the invention comprises a water-soluble amphiphilic copolymer chosen from:

- (i) at least one polymer obtained by polymerization
 - of at least one ethylenically unsaturated monomer (I) of monocarboxylic or polycarboxylic acid type, or a carboxylic acid precursor of cyclic, linear or branched aliphatic or anhydride type, and
 - of at least one monoethylenically unsaturated linear or branched hydrocarbon-based monomer (II),
- (ii) at least one polymer derived from the polymerization of at least one monocarboxylic or polycarboxylic acid monomer (I) or cyclic, linear or branched, ethylenically unsaturated aliphatic anhydride, and comprising at least one saturated or unsaturated C₄-C₃₀ hydrocarbon-based hydrophobic graft, optionally interrupted with one or more hetero atoms,
- (iii) at least one polymer obtained by chemical

modification, for instance esterification, transesterification or amidation, of a precursor polymer on the one hand comprising sites onto which a hydrophobic graft may be grafted, for instance
 5 carboxylic acid or ester sites, this graft on the other hand comprising carboxylic acid units or carboxylic acid precursor units.

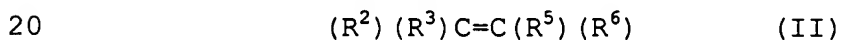
According to one particular embodiment of the first variant (i), mention may be made firstly of
 10 polymers derived from the polymerization:

- of at least one monomer (I) having the following formula:



in which formula the radicals R^1 and R'^1 , which may
 15 be identical or different, represent a hydrogen atom, a C_1 - C_{10} hydrocarbon-based radical optionally comprising a $-COOH$ group, or a $-COOH$ group; and

- of at least one monomer of formula (II) having the following formula:



in which formula:

- the radical R^2 represents a hydrogen atom or a linear or branched C_1 - C_{10} alkyl radical optionally substituted with hetero atoms;
- 25 - the radical R^3 represents a linear or branched C_1 - C_{10} alkyl radical optionally substituted with hetero atoms, or a radical $-O-R^4$,

i.e. a vinyl ether, with R^4 representing a linear or branched C_1 - C_{10} alkyl radical optionally substituted with hetero atoms;

- the radical R^5 represents a hydrogen atom or a
5 linear or branched C_1 - C_{10} alkyl radical optionally substituted with hetero atoms;

- the radical R^6 represents a hydrogen atom or a linear or branched C_1 - C_{10} alkyl radical optionally substituted with hetero atoms;

10 it being understood that at least one of the radicals R^2 , R^3 , R^5 or R^6 represents a linear or branched C_1 - C_{10} alkyl radical optionally substituted with hetero atoms.

According to one preferred embodiment of the
15 invention, the monomer of formula (I) is such that one of the radicals R^1 is a hydrogen atom; the other radical R^1 represents a hydrogen atom, a $-COOH$ group or a group $-(CH_2)_n-COOH$ in which n is between 1 and 4, or a C_1 - C_4 alkyl radical; R'^1 represents a hydrogen atom, a group
20 $-(CH_2)_m-COOH$ in which m is between 1 and 4, or a C_1 - C_4 alkyl radical.

Preferably, one of the radicals R^1 represents a hydrogen atom, the other radical R^1 represents a hydrogen atom, a $-COOH$ or $(CH_2)-COOH$ group or a methyl
25 radical, and R'^1 represents a hydrogen atom, a $-CH_2COOH$ group or a methyl radical.

According to a more particular embodiment,

the monomer of formula (I) is chosen from acrylic, methacrylic, citraconic, maleic, fumaric, itaconic or crotonic acid or anhydride.

Even more preferably, the monomer of formula
5 (I) is maleic anhydride.

As regards the monomer of formula (II), it may be chosen especially from ethylene, propylene, 1-butene, isobutylene, n-1-pentene, 2-methyl-1-butene, n-1-hexene, 2-methyl-1-pentene, 4-methyl-1-pentene, 2-
10 ethyl-1-butene, diisobutylene (or 2,4,4-trimethyl-1-pentene) or 2-methyl-3,3-dimethyl-1-pentene, or, for the vinyl ethers, from isobutyl vinyl ether, methyl vinyl ether, 1-menthyl vinyl ether, phenyl vinyl ether or octadecyl vinyl ether.

15 Preferably, the copolymer of formula (i) is derived from the polymerization of maleic anhydride and isobutylene.

It is pointed out that the polymer (i) is obtained more particularly by performing a free-radical
20 polymerization of the monomers (I) and (II).

These compounds are well known to those skilled in the art. Polymers of this type that may be mentioned include the product sold under the name Geropon® T36 (maleic anhydride/diisobutylene), sold by
25 Rhodia Chimie, Sokalan® CP9 (maleic anhydride/olefin) sold by BASF, and the Gantrez resins sold by the company ISP.

In the case where a water-soluble amphiphilic copolymer as described above is added to the composition according to the invention, the said copolymer advantageously represents 0.1% to 5% by weight relative to the total weight of hydraulic binder.

The fibres may be natural or artificial fibres chosen, for example, from the group consisting of glass fibres, carbon fibres, steel fibres, polyamide fibres, polyester fibres, poly(vinyl alcohol) fibres, polypropylène fibres, ceramic fibres and poly(acrylonitrile) fibres, derivatives thereof and/or mixtures thereof.

The polyamide fibres used will advantageously be those usually used in the field of textile articles or yarns and fibres for technical applications. By way of example, the polyamides that may be used in the present invention comprise PA 6.6, PA 6, the copolymer PA 6.6-PA 6, semiaromatic polyamides, such as polyamide 6T, Amodel® (sold by the company Amoco), HTN® (sold by the company DuPont), other polyamides 11, 12 and 4-6, for example, copolyamides and/or blends thereof. The polyamides may be of linear or branched structure, for instance the starburst polyamide sold by the company Rhodia under the brand name Technylstar®. According to the invention, it is possible for the polyamide fibres to be pretreated with one or more additives.

Preferably, the composition according to the invention comprises a water-soluble amphiphilic copolymer as described above, a latex and optionally fibres.

5 Preferably, the hydraulic binder is based on at least one compound chosen from the group consisting of calcium silicate (Portland cement), calcium sulphate (plaster) and calcium phosphate or other phosphates (dental cement). The hydraulic binders may also be
10 packaged as a mixture with other additives such as sand or gravel, for example, to form a ready-to-use mortar.

The present invention also relates to a composition for manufacturing an article comprising one or more superposed layers each less than 5 centimetres
15 thick, comprising a hydraulic binder and at least one compound chosen from:

- an organic compound comprising at least two hydrophilic functions and a hydrophobic chain, and
- a polyamide oligomer comprising less than 20
20 repeating units and preferably less than 10 repeating units.

This composition may also comprise at least one compound chosen from the group consisting of a latex, a water-soluble amphiphilic copolymer and
25 fibres. The latices, the water-soluble amphiphilic copolymer and the fibres are the same as defined above.

The present invention also relates to an

article comprising one or more superposed layers each less than 5 centimetres thick, obtained according to the manufacturing process and/or from the composition as defined above.

5 The articles according to the invention may be tiles, boards, panels, tubes, blocks, tanks, paving stones, flagstones or partitions, for example, or articles of covering type such as coatings, grouts or screed floors, for example.

10 Preferably, the article is less than 5 centimetres thick, advantageously less than 2 centimetres and preferably less than or equal to 1 centimetre in thickness.

 The present invention also relates to the use
15 of a composition as defined above for the manufacture of an article comprising one or more superposed layers each less than 5 centimetres thick, such as a coating, a covering or a grout.

 The present invention also relates to the use
20 of a composition as defined above for the manufacture of an article comprising one or more superposed layers each less than 5 centimetres thick, such as a fibrocement.

Example 1

25 Cement cakes are prepared according to a process consisting in filtering a suspension of cement, fillers and additives in the presence of 0%, 0.5% or 1%

of additives chosen from adipic acid alone, or a mixture of adipic acid and latex powder based on acetate-versatate copolymer (50/50 or 25/75, respectively).

5 The composition used comprises 30% cement (sold by Lafarge under the reference HTS 52.5) diluted in water with a water/cement ratio = 3 (W/C).

 The slurry comprising the additives is filtered to obtain a cement cake. The cakes are left
10 for 24 hours in an air-conditioned room at 25°C and with a relative humidity (RH) of 60% before testing. The cakes are approximately 1 centimetre thick.

 The results are given in Table 1.

Table 1

15

Additives	Adipic	Adipic + PAV 50/50	Adipic + PAV 25/75
0%	Pronounced cracking	Pronounced cracking	Pronounced cracking
0.5%	Slight cracking	No cracking	Slight cracking
1%	No cracking	No cracking	No cracking

 Adipic + PAV 50/50 represents a mixture of 50% by weight of adipic acid and 50% by weight of PAV.

 Adipic + PAV 25/75 represents a mixture of 25% by weight of adipic acid and 75% by weight of PAV.

20 These results show an improvement in the performance of the cement by adding additives such as adipic acid or adipic acid and acetate-versatate latex (PAV) powder.

Example 2

The cement objects obtained in Example 1 are subjected to two tests measuring the water uptake and the water absorption.

5 The water absorption measurement is performed by exposing the additive-containing cement objects obtained in the above example, dried beforehand for one hour in an oven at 80°C and weighed, in a chamber with a relative humidity (RH) of 75% at 25°C for 2, 5 and 12
10 days.

The water drop test consists in measuring the time required for the penetration of four drops of deionized water deposited, at room temperature and after the same drying process as previously, onto the
15 surface of the cement object obtained in the example.

The results are given in Table 2.

Table 2

	% of additives	Water absorption (75% RH, 25°C)			Water drop test
		2 days	5 days	12 days	Absorption time (s)
Control	0	1.28	2	2.52	4
Adipic	0.5	0.75	1.38	1.81	7
Adipic-PAV 50/50	0.5	0.98	1.6	2.11	16
Adipic-PAV 50/50	1	0.89	1.49	1.99	34
Adipic-PAV 25/75	0.5	0.85	1.58	2.08	8

Adipic-PAV 25/75	1	0.82	1.38	1.82	17
---------------------	---	------	------	------	----

These results show that better water resistance is obtained with cement comprising additives such as adipic acid or adipic acid and acetate-versatate latex powder.

5 Example 3

The cement compositions below are prepared using a mixer:

Composition		1	2	3
Cement sold by Lafarge under				
10 the reference HTS 52.5		100	100	100
Fumed silica sold by Elkem				
under the reference 940 U		10	10	10
Adipic acid			0.4	2
PAV22 latex			0.3	1.5
15 Geropon T36			0.3	1.5
Water		50	50	50

A measurement of the density of these suspensions is then performed (by weighing 250 cm³ of this suspension) and it is found that the additive
20 system according to the invention allows a lowering of this density.

Density of the cement paste	1.92	1.64	1.42
-----------------------------	------	------	------

This suspension is then cast into 16x4x4 cm moulds, so as to prepare specimens on which several
25 types of measurements will be performed. These specimens are left to age for 30 days at room

temperature before performing these measurements, which are:

- the density of the specimens, to determine the "lightening" capacity of the additive system

5	Composition	1	2	3
	Density of the cement article			
	after setting and ageing for			
	30 days	1.65	1.47	1.21

- their behaviour with respect to water (hydrophobicity or pearling effect) using the water drop test as described in Example 2, after drying the specimens under the same conditions as in Example 2. The test is performed both on the outer surface of the specimen and on the inner surface of the specimen after the said specimen has been broken (test performed at the break).

		Absorption Time		
	Composition	1	2	3
	Outer surface of the specimen	3 min	15 min	>30 min
20	Inner surface of the specimen	15	5 min	>30 min
	(after breaking)	seconds		

- the 3-point bending mechanical strength properties, according to the measurement method described below in Example 4:

25	Composition	1	2	3
	Maximum stress (σ max in kN)	0.3	0.35	0.51

The compression properties of the specimens

of compositions 2 and 3 are not prohibitively degraded compared with the specimen of composition 1, despite the lowering in density provided by these compositions 2 and 3.

5 Example 4

Various composite materials of fibrocement type, 5 millimetres thick, were prepared as indicated below.

10 The composition of the fibrocement used in the examples is as follows:

-	cement sold by Lafarge under the reference HTS 52.5	200 g
-	fumed silica sold by Elkem under the reference 940 U	35 g
15 -	cellulose extracted from <i>Pinus radiata</i>	10 g
-	polyamide reinforcing fibres	5 g
-	additives	2 g
-	water	750 g

20 The cellulose is first pulped for one hour with vigorous stirring and the other ingredients are then added. After blending for 15 minutes, the mixture is poured into a mould and a primary gentle suction is applied. The resulting cake is then subjected to a pressure of 10 tons (10 MPa) in order to form the
 25 samples. For each formulation, 6 fibrocement specimens are manufactured: 120 × 30 × 5 mm in size.

These specimens are left for 24 hours at room

temperature in a chamber saturated with moisture, and are then matured for 24 hours at 60°C in a chamber that is again saturated with moisture, and finally left for at least 24 hours in an air-conditioned room at 20°C
5 with a relative humidity (RH) of 65% before testing.

The mechanical tests are performed in 3-point bending (inter-axis: 100 mm), at a test speed of 0.1 mm/min. This test is a standard 3-point bending test. The force-displacement curve is recorded and the
10 equivalent stress corresponding to the maximum load (σ_{\max}) is calculated. The equivalent stress corresponding to a 2 mm bend of the specimen is also calculated.

In all cases, no sign of cracking is noted on
15 the edges of the specimens, even during long-term ageing of the products.

Table 3 shows the relative increase in the maximum stress obtained during the test of a fibrocement reinforced with additive, compared with the
20 maximum stress obtained during the test of a fibrocement without additive. This relative increase is noted as $\Delta\sigma_{\max}$.

Table 3

Additive	$\Delta\sigma$ max
PA acid oligomer	+30%
PA AISNa oligomer	+7%
Adipic	+20%
Adipic + Latex PAV22 (50/50)	+22%
Latex PAV22	+10%

The PA acid oligomer is obtained by condensation of adipic acid and hexamethylenediamine with an acid stoichiometry of 20% relative to the equilibrium stoichiometry (1 mol of diacid per 1 mol of diamine) comprising about 8 to 14 units.

The PA AISNa oligomer is a sodium salt of sulphonated polyamide oligomer obtained by polycondensation of 3 monomers (adipic acid, hexamethylenediamine and sulphonated isophthalic acid) comprising about 8 to 14 units.

PAV22, of trade name Rhoximat® PAV22, is a latex powder based on acetate-versatate copolymer.

The curves representing the stress tolerated as a function of the bending of the specimen are given in Figure 1 (fibrocements with polyamide fibres and addition of polyamide oligomers) and in Figure 2 (fibrocements reinforced with polyamide fibres and addition of adipic and/or latex).

In these figures, the x-axes correspond to the bending of the specimen in millimetres, and the y-axes correspond to the bending stress in MPa.

The polyamide fibres used are the following:

- PA 0.6 dtex fibre: this is a polyamide 66 fibre of thin, round cross section, produced by Rhodia Technical Fibers for Flock application. It is a non-twist fibre
5 chopped to 6 mm, the mechanical characteristics of which are especially an elongation at break of 80%.
- PA 0.5 dtex fibre: this is a polyamide 66 fibre of ultra-thin, round cross section, produced by Rhodia Technical Fibers for Flock application. It is a non-
10 twist fibre chopped to 6 mm, the mechanical characteristics of which are especially an elongation at break of 20%.

In Figure 1:

- Curve A corresponds to the polyamide fibres (PA
15 0.5 dtex fibre) alone;
- Curve B corresponds to the mixture of polyamide fibres (PA 0.5 dtex fibre) and of acid polyamide oligomer; and
- Curve C corresponds to the mixture of polyamide
20 fibres (PA 0.5 dtex fibre) and of AISNa oligomer.

In Figure 2:

- Curve A corresponds to the polyamide fibres (PA 0.6 dtex fibre) alone;
- Curve D corresponds to the mixture of polyamide
25 fibres (PA 0.6 dtex fibre) and of PAV22;
- Curve E corresponds to the mixture of polyamide fibres (PA 0.6 dtex fibre), of adipic acid and of PAV22

(50/50: adipic/PAV22), and;

- Curve F corresponds to the mixture of polyamide fibres (PA 0.6 dtex fibre) and of adipic acid.

The maximum stress tolerable by the fibrocement is increased in the presence of additives. Furthermore, the ductility of the material may be substantially increased by adding an additive, which represents an appreciable improvement in the working properties.

The results obtained in Figures 1 and 2 show the advantage of using fibres with a low yarn count to obtain a maximum gain both in the maximum stress tolerable by the material and in its ductility.

Example 5

Various composite materials of fibrocement type, 5 millimetres thick, were prepared as indicated below.

The composition of the fibrocement used in the examples is as follows:

20	-	cement sold by Lafarge under the reference HTS 52.5	200 g
	-	fumed silica sold by Elkem under the reference 940 U	35 g
	-	cellulose extracted from <i>Pinus radiata</i>	10 g
25	-	reinforcing fibres	5 g
	-	additives	2 g
	-	water	750 g

The cellulose is first pulped for one hour with vigorous stirring and the other ingredients are then added. After blending for 15 minutes, the mixture is poured into a mould and a primary gentle suction is applied. The resulting cake is then subjected to a pressure of 10 tons (10 MPa) in order to form the samples. For each formulation, 6 fibrocement specimens are manufactured: 120 × 30 × 5 mm in size.

These specimens are left for 24 hours at room temperature in a chamber saturated with moisture, and are then matured for 24 hours at 60°C in a chamber that is again saturated with moisture, and finally left for at least 24 hours in an air-conditioned room at 20°C with a relative humidity (RH) of 65% before testing.

The mechanical tests are performed in 3-point bending (inter-axis: 100 mm), at a test speed of 0.1 mm/min. This test is a standard 3-point bending test. The force-displacement curve is recorded and the equivalent stress corresponding to the maximum load (σ_{\max}) is calculated. The equivalent stress corresponding to a 2 mm bend of the specimen is also calculated.

In all cases, no sign of cracking is noted on the edges of the specimens, even during long-term ageing of the products.

The following additive system was used (the percentages given are weight percentages):

- Latex PAV22 40%
- Adipic 40%
- Geropon T36 20%

These additives are used at a content of 1%
5 by weight relative to the cement.

The fibres used are polyamide PA 6.6 fibres
of 78f136 type chopped to 6 mm, or APV RM 182® fibres
sold by the company Kurarray, chopped to 6 mm.

The maximum stress tolerable by the
10 fibrocement in the presence of fibres (APV or PA) is
maintained in the presence of additives.

Furthermore, the density of the materials is
substantially reduced.

Finally, the hydrophobic power is markedly
15 improved in the presence of the additives.